California Inspection and Maintenance Review Committee

Smog Check II Evaluation

Part IV: Smog Check Costs and Cost Effectiveness

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1. Introduction and Summary of Results

The IMRC has attempted to answer the following questions about the costs of the Smog Check program:

1. What does the Smog Check program cost overall?
2. To what extent are Smog Check expenditures targeted toward repair of high-emitting vehicles?
3. What is the *cost effectiveness* of Smog Check? That is, how much pollution reduction does the program achieve per dollar spent?
4. Do Smog Check costs and cost effectiveness change for different portions of the vehicle fleet?

Results can be summarized as follows:

Statewide Costs

- Smog Check costs about $850 million per year statewide, with about 70 percent of costs generated by the Enhanced Program.
- About 28 percent of Smog Check costs are spent on vehicle repairs. The remaining 72 percent of costs are spent on emission testing, program administration, and the cost of motorists' time.
- Smog Check repairs increase average fuel economy of the vehicle fleet, thereby offsetting some of the costs of Smog Check. The level of these savings is uncertain, but could be in the range of $50 million to $100 million per year (given current gasoline prices).

Direct Costs to Motorists

- Enhanced Smog Check costs motorists an average of about $65 if their vehicles pass and about $230 if their vehicles fail. Gasoline savings offset some of the costs to owners of failing vehicles. Owners of older vehicles and those with lower incomes are more likely to own a vehicle that fails Smog Check and thus to incur the highest costs.

Cost Effectiveness

- Enhanced Smog Check costs about $5,400 per ton of pollution reductions. This estimate includes estimates of non-tailpipe hydrocarbon benefits and gasoline cost savings due to improved fuel economy. This cost effectiveness is competitive with the cost effectiveness estimated for other major mobile source air pollution reduction measures such as low-emission vehicles, vehicle retirement, and reformulated gasoline.
- In 1999, pre-1991 vehicles accounted for about 95 percent of Enhanced Smog Check benefits, but only about 60 percent of total costs.
- Smog Check's cost per ton of emission reductions is much lower for older vehicles than for newer vehicles. Emission reductions cost on average about $3,500 per ton for vehicles of at least 10 years of age (1990 and older model years

in calendar year 1999) and $35,000 per ton for vehicles less than 10 years old (1991 and newer vehicles in 1999).

2. What Are the Overall Costs of Smog Check?

This section examines the overall costs of the Smog Check program and on what activities the money is spent. Smog Check program costs fall into four major categories, as follows: (1) vehicle testing, (2) vehicle repair, (3) program administration, and (4) the value of the time motorists spend in the Smog Check process. Table 1 displays estimates for each of these costs for both the Basic and Enhanced Programs.[1] As the table shows, the Smog Check program costs an estimated total of $854 million per year statewide, with the Enhanced Program accounting for $609 million, or 71 percent of total costs.[2] The rest of this section describes how the IMRC derived these cost estimates.[3]

Table 1. Statewide Annual Costs of the Smog Check Program*

	Costs (in $millions)			Percent of Costs		
Cost Element	**Enhanced**	**Basic**	**Statewide**	**Enhanced**	**Basic**	**Statewide**
Testing (excludes retests)	335	132	466	55	54	55
Repairs (includes retests)	176	61	237	29	25	28
Administration	46	25	71	7	10	8
Motorist Time	52	27	80	9	11	9
Totals	609	245	854	100	100	100

* Numbers may not add due to rounding.

[1] Costs for the Change-of-Ownership program (meaning the areas of the state in which testing is required *only* upon change of ownership and not bienially), which account for less than 2 percent of all program costs, are subsumed within the Basic Program category in all of the cost estimates.

[2] Some of the costs of Smog Check are offset by fuel economy savings due to Smog Check repairs. It was not possible to make a detailed estimate of savings from increased fuel economy for this report. However, based on a study of the Arizona I/M program (Ando, et al. (1999) "Costs, Emissions Reductions, and Vehicle Repair: Evidence from Arizona," Resources for the Future, Discussion Paper 99-23-REV Revised October 1999) and current California gasoline prices, these savings are likely in the range of $50 million to $100 million per year statewide.

[3] *Note that costs are reported here with great precision – to the nearest million dollars. With the exception of program administration, none of these costs are known that accurately. They are reported to the nearest million so that the various breakdowns of costs in other tables later in this report will all reconcile with each other. Keep in mind that these are estimates and are subject to various degrees of uncertainty that will be discussed later in this document.*

2.1. Vehicle Testing Costs

Motorists might pay for up to three different kinds of Smog Check tests:

- ***Pretest.*** An optional test that allows motorists to find out if their vehicles are likely to fail the official test.
- ***"Official" Initial Smog Check Test.*** This is the test that initially determines whether a vehicle officially passes or fails. The majority of tests fall into this category. These tests will henceforth be referred to as an "initial Smog Check."
- ***Retest.*** Vehicles that fail their first official test must pass a subsequent official retest in order to receive a certificate of Smog Check compliance and be legally registered.

Table 2 lists the breakdown of costs among the three types of tests for both the Basic and Enhanced programs. As the table shows, most testing expenditures are directed toward initial Smog Checks.

Table 2. Breakdown of Costs among Initial Smog Checks, Pretests, and Retests

	Costs (in $millions)			
Test Type	**Enhanced**	**Basic**	**Total**	**Percent of Costs**
Initial Smog Checks	320	124	443	88
Pretests	15	8	23	5
Retests	25	12	38	8
Totals	360	144	504	100

Initial Smog Checks. One must estimate the following factors in order to determine costs for initial Smog Checks: (1) number of vehicles tested in the Basic and Enhanced programs, and (2) the average cost per test in the Basic and Enhanced programs. The product of the number of vehicles tested and the cost per test gives the value for total expenditures.

In 1999, roughly 3.7 million Smog Check certificates were awarded in the Basic Program and 6.7 million certificates were awarded in the Enhanced Program.[4] These numbers are derived as follows. First, according to BAR, about 10.3 million Smog Check certificates were sold in 1999. This number is assumed to be the number of vehicles that

[4] This estimate for the number of Smog Checks in a year includes the fact that some vehicles receive more than one Smog Check in a year. This is because vehicles that change ownership can have two Smog Checks in the same year. Each of these Smog Checks counts as a different Smog Check cycle with its own initial test.

complete the Smog Check process each year. One must add to this number tests of vehicles that are tested and fail but do not receive a certificate because they never pass. In the Enhanced Program, LBNL's analysis of BAR's Smog Check database (see Part III of this report) indicates that about 1.3 percent of vehicles tested fall into this category (10.4 percent of failing vehicles). Assuming that 10.4 percent of vehicles that fail in the Basic Program also never pass, one must add about 150,000 to the estimate of initial tests. The number of initial Smog Checks then comes to about 10.5 million. Second, based on Vehicle Information Database (VID) data summarized in BAR's Executive Summary reports,[5] the Enhanced Program accounts for 64 percent of tests, while the Basic and Change-of-Ownership programs account for the remaining 36 percent of tests.

The average cost of a Smog Check in the Enhanced Program is about $48. The average cost in the Basic Program is about $33. These costs were determined through a telephone survey of about 400 Smog Check stations conducted in the fall of 1999. The caller posed as a potential customer and inquired about the price of a Smog Check. Random samples of each station type were surveyed separately in each program area in order to gather statistically valid information on potential price differences by station type.[6] The results are displayed in Table 3.[7] Average costs per test for the Basic and Enhanced programs were derived by weighting the cost results for each station type by the percentage of the vehicle fleet tested at each station type.[8]

Pretests and Retests. Once again, total costs were estimated by multiplying the total number of tests by the average price per test. Data were collected on the price for pretests and retests during the telephone surveys. Based on the survey data, pretests and retests cost an average of $22 and $20 respectively in the Enhanced Program, and $21 and $27, respectively, in the Basic Program. These figures include a substantial percentage of stations that do not charge for pretests or retests (32% and 49%, respectively in the Enhanced Program, and 18% and 16% in the Basic Program).

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[5] On the Web at http://www.smogcheck.org/smogweb/smog/statistics.asp

[6] The IMRC is grateful to its secretary, Bridget Fitzsenry, for going beyond the call of duty to conduct these surveys.

[7] The exact values from the survey were $47.55 and $33.12 for Enhanced and Basic average testing costs, respectively, and are the numbers used in the cost calculations. Once again, remember that these are estimates. Actual average testing costs are not known to the nearest penny.

[8] If more cars were tested at stations that charge less for the test, this method would overestimate testing costs. However, there is little or no correlation between what a station charges for the test and the number of initial tests it performs each year. This is true for the whole sample of stations and also within individual station types. To check the relationship between price charged per test and number of tests performed, cost data from the survey were merged with VID data on the number of initial tests performed by each station in the survey over the course of a year. Correlation coefficients were calculated for the whole sample and within each individual station type. Correlations for the relationship between testing costs and number of initial Smog Checks performed were less than 0.14 and were not statistically significant.

Table 3. Price of a Smog Check by Station Type and Program Region[9]

Station Type	Enhanced	Basic
Test-and-Repair	$48	$32
Test-Only [10]	$49	--
Gold Shield	$44	$31
Gross Polluter Cert.	$51	$38
Program Average	$48	$33

To determine the number of pretests performed, LBNL analyzed data from the VID, counting all tests coded as pretests in the database. This analysis showed that 5 percent of vehicles received official pretests. Some vehicles likely also receive "unofficial" pretests. An unofficial pretest would occur if a Smog Check shop checks the emission status of a vehicle without recording valid vehicle information in the VID. This analysis assumes that 5 percent of Enhanced vehicles and 3 percent of Basic vehicles receive unofficial pretests and that pretest costs for these vehicles are the same as for official pretests.[11]

For retests, all failing vehicles are assumed to receive one retest at the average retest cost. No retest costs were assumed for vehicles that receive repairs before their first official test.

2.2. Repair Costs

The IMRC estimated repair costs by multiplying the number of vehicles that fail and then pass by the average repair cost. These two numbers were estimated as follows:

Number of Vehicles. The number of repaired cars is estimated at about 1.1 million per year in the Enhanced Program and 400,000 per year in the Basic and Change-of-Ownership programs. These numbers were calculated by multiplying the number of cars tested in each program by the percentage of cars that fail in each program, and then adjusting the result downward for the portion of cars that fail and never pass. Failure rates are 13.7 percent in the Enhanced Program, 9.0 percent in the Basic Program, and 11.9 percent in the Change-of-Ownership program during Phase 4 (i.e., current) cut points.[12]

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[9] Within each program area, differences in testing costs by station type were found to be statistically significant via a statistical technique called one-way analysis of variance.

[10] There are only eight test-only stations in the Basic Program. Basic test-only stations were not included in the survey.

[11] The unofficial pretest assumption for the Enhanced Program is based on the assumption that 75% of the difference between on-road and Smog Check failure rates is due to unofficial pretests.

[12] The failure rate in the Enhanced Program includes official pretests. The failure rates for the Basic and Change-of-Ownership programs include the assumption that including pretests increases the estimated

In addition, costs were estimated for pre-Smog Check repairs. Some vehicles are likely repaired before their first official Smog Check or official pretest. These vehicles presumably would have failed their Smog Check if they had not received repairs beforehand. As noted above, pre-Smog Check repairs are assumed to increase the percent of the fleet receiving repairs by 5 percentage points in the Enhanced Program and 3 in the Basic Program above the number estimated from the observed failure rate alone.

Average Cost of Repair. Average repair costs are based on BAR's estimate from data contained in the Vehicle Information Database (VID), the electronic storehouse of all Smog Check vehicle test and repair information. Mechanics are required to enter information on types of repairs and repair costs into the VID for each vehicle that they work on. However, according to BAR, these data are entered haphazardly by mechanics. Based on the repair records that do exist, repair costs average $128 per vehicle in the Enhanced Program and $118 per vehicle in the Basic and Change-of-Ownership programs. The same average repair cost estimate was used for vehicles assumed to receive pre-Smog Check repairs.

2.3. Administrative Costs

The Governor's proposed budget for 2000-01 includes $71 million for Smog Check administration.[13] Table 4 lists budgeted amounts for each activity performed by BAR. BAR's administrative funds come from two primary sources. First, motorists pay a state fee of $8.25 for a "certificate of compliance" when they pass their Smog Check. These fees are deposited into the Vehicle Inspection and Repair Fund (VIRF). Certificate fee revenues totaled about $79 million in the 1998-99 fiscal year. Based on current trends, certificate sales will increase to $81 million in the 1999-00 fiscal year.

Second, motorists who own vehicles four model years old and newer must pay a Smog Abatement Fee (SAF) of $6 when they register their vehicles each year. These funds are applied to Smog Check as follows. The $6 paid by motorists upon first registration of a new vehicle and $2 of the registration fee paid for vehicles aged two, three, and four years go into the High Polluter Repair and Removal Account (HPRRA) and fund the Repair Assistance Program (RAP) and the Vehicle Retirement Program (VRP). These funds replace a portion of the funds lost when the Smog Impact Fee was invalidated by the courts in 1999. The $3.6 million budgeted for RAP and VRP administration comes from these monies (the rest of the funds are used to fund the actual costs of repairing or retiring vehicles). This $3.6 million is the only money from the HPPRA that is used for administration. The remaining $4 registration surcharge paid by motorists owning two-, three-, and four-year old vehicles goes into the VIRF and is used along with certificate fees to fund BAR's budget.

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failure rate by 24%, the same amount as in the Enhanced Program. The fraction of failing vehicles that never pass is assumed to be the same in the Basic Program as it is in the Enhanced Program.

[13] The Budget includes an additional $26.3 million for Consumer Protection Operations. This includes general oversight of the automotive repair industry separate from the Smog Check program. The funds for these activities come from registration and licensing fees from automotive repair dealers.

Table 4. The Smog Check Budget

	Budgeted Amounts by Fiscal Year (in $thousands)		
Function	**1998-99**	**1999-00**	**2000-01**
Smog Check Engineering and Operations	29,263	36,764	36,559
Enforcement	14,703	15,624	15,702
Mediation	3,629	5,640	5,640
Consumer Information Center	5,007	7,448	4,146
Administration for RAP and VRP	3,346	3,826	3,630
Special Projects	2,796	2,993	2,993
Licensing	1,401	1,550	1,550
Education	773	774	775
TOTAL Smog Check Administration	**60,918**	**74,619**	**70,995**

2.4. Costs for Motorists' Time

Motorists spend time completing the Smog Check process. This time has a value that economists refer to as an "opportunity cost"—the cost incurred by spending time on Smog Check, rather than on other activities that motorists might perceive as having greater value for them. Time costs to motorists include the following: (1) time to drive to and from a Smog Check station, (2) time to get a Smog Check, and (3) time to drive to and from a repair station (if testing occurred at a test-only station). In addition, some motorists might lose the use of their vehicle while it is repaired. Data are not available that would allow accurate estimation of the amount of time required for these activities. In the absence of data, it was assumed that the average motorist spends 45 minutes to complete the Smog Check process for a passing vehicle and 90 minutes for a failing vehicle, including travel time to and from stations.

Economic studies suggest that people value their free time at somewhere between 50 percent and 100 percent of their after-tax wage rate.[14] For this calculation, it was assumed that motorists' time is valued at $8.71 per hour, 75 percent of the estimated average after-tax manufacturing wage in California.[15] As noted earlier, some Smog Check-related repairs likely occur before the first official test. Vehicles assumed to

[14] McConnell, V. D. (1990) "Costs and Benefits of Vehicle Inspection: A Case Study of the Maryland Region," *Journal of Environmental Management*, vol. 30, pp. 1-15.

[15] California Employment Development Department (2000) "Average Hourly Earnings in Manufacturing," February 25, 2000.

receive pre-Smog Check repairs were treated as failing vehicles for the purposes of calculating the cost of motorists' time.

2.5. Uncertainties in Cost Estimates

The above estimates of program costs include a number of uncertainties.

Testing Costs. Certificate sales are subject to financial tracking and auditing by the Department of Consumer Affairs. This number is therefore likely to be relatively accurate. The margin of error in the cost survey is about 4 percent. Thus, the number of initial Smog Checks and the cost per Smog Check appear to be relatively accurately known as well.[16]

About 5 percent of vehicles receive an official pretest in the Enhanced Program. Unofficial pretests were assumed to add an additional 5 percent of the fleet for a total pretest rate of 10 percent of the fleet in the Enhanced Program. However, the true rate of pretesting could be significantly different from this. If the actual pretest rate is 50 percent lower than estimated here, total Smog Check costs would drop by $12 million or 1.4 percent of total Smog Check costs.

The number of retests is relatively well known assuming that both the number of initial Smog Checks and the failure rates are accurate. Some failing vehicles may receive more than one retest, although it is not known whether motorists are typically charged for a second retest. The cost estimate included the assumption that the average failing vehicle requires one retest at the average retest cost, regardless of the number of retests. No retest costs were assumed for vehicles that receive pre-Smog Check repairs. Like pretests, retests account for a small percentage of testing costs and so will not have a large effect on the accuracy of the overall cost estimate.

Repair Costs. Four factors combine to make repair expenditure estimates the most uncertain of the four cost elements. The first three factors involve uncertainty in the number of vehicles repaired. The fourth involves uncertainty in the average cost of repair.

First, some motorists likely perform maintenance on their vehicles *before their initial Smog Check or official pretest.* This analysis assumes that about 5 percent of vehicles receive repairs before their first official test. Although 14 percent of vehicles fail their official Smog Check under Phase 4 cut points, 21 percent of vehicles fail when tested at random on the road.[17] It is possible that some of this difference is due to pre-Smog Check repairs, which would lower the failure rate observed on the Smog Check test. However, the discrepancy between the roadside data and the official Smog Check results could also be due to fraud or Smog Check avoidance by some on-road vehicles. This analysis assumes that 75 percent of the difference between on-road and Smog Check test failure

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[16] Bear in mind, however, that Smog Check costs do vary with time, most likely due to competitive conditions within the Smog Check market. For example, testing costs in the Enhanced Program appear to have dropped by about 10% since the start of the program, perhaps due to a concomitant 6% increase in the number of Smog Check stations.

[17] This is the fleet-average failure rate for 1974-1999 vehicles in the roadside data, including only vehicles that have a previous Smog Check record.

rates is due to pre-Smog Check repairs. However, the actual value could be substantially different.

Second, some vehicles might fail and then pass their Smog Check *without any repairs having been performed*. This could occur for several reasons. For example, the vehicle might not have been properly warmed up before it was tested. Vehicles operating in such a "cold start" mode have higher emissions for a few minutes until their catalytic converter heats up. Mechanics might sometimes improperly pass a genuinely high-emitting vehicle. Motorists might avoid repair due to natural emissions variability of their vehicles. Many vehicles exhibit emissions variability from test to test. Motorists or mechanics might try retesting a failing vehicle without making any repairs in the hope that the emissions will be lower the second time around. To the extent that any of these circumstances obtain, assuming all failing vehicles have repairs performed would cause an *overestimate* of repair costs generated by Smog Check. [18]

Third, some costs might be incorrectly credited as costs of the Smog Check program. Vehicles that receive repairs and/or maintenance fall into three categories in relation to costs:

(1) vehicles that would have failed without repairs and/or maintenance and *would not* have received them if Smog Check did not exist;

(2) vehicles that would have failed without repairs and/or maintenance but *would* have received them even if Smog Check did not exist;

(3) vehicles that would have passed even without repairs and/or maintenance, but *would not* have received them if Smog Check did not exist (i.e., vehicles for which Smog Check causes unneeded repairs and/or maintenance).

Only groups (1) and (3) are costs generated by the Smog Check program. Vehicles in the second group would be repaired and/or maintained even without the existence of Smog Check (though Smog Check might affect the timing of when this occurs). The IMRC has no way to determine how many vehicles fall into this second group. This factor would cause an *overestimate* of the repair costs generated by Smog Check.

Fourth, the estimate of average repair costs might be inaccurate. Average repair costs were provided by BAR based on their analysis of VID data. Each time a "round" of repairs is performed on a vehicle, the technician is supposed to enter a repair record into the VID. BAR calculated repair costs for each vehicle by adding up the repair costs reported in all repair records for a vehicle in a given Smog Check cycle. These data might not reflect actual repair costs. For example, technicians might in some cases (1) report repair costs incorrectly, (2) enter incomplete information, or (3) not enter repair

[18] As noted in Part III of this report, a large sample of on-road remote sensing measurements (one million or more measurements) could provide information on the extent to which pretest repairs and post-failure avoidance are occurring. Such an analysis has already been successfully performed using remote sensing data collected in Arizona (see Wenzel, T. (1999) "Evaluation of Arizona's Enhanced I/M Program", presentation to the NRC Committee to Review the MOBILE Model, Lawrence Berkeley National Laboratory, Berkeley, California). In addition, the IMRC will be conducting focus groups with motorists and mechanics in order to learn more about how they maintain their vehicles and how they behave in the Smog Check process. The results of this study should be available this summer.

information at all. In addition, repairs might sometimes be performed by unlicensed technicians or by motorists themselves. Such repairs would not be recorded in the VID. Any of these factors could bias the data used to estimate average repair costs. The IMRC was not able to evaluate the quality of VID repair-cost data during the time available for this study, but plans to do so in the future.

Given the uncertainties in the number of vehicles repaired, the extent to which repairs are caused by Smog Check, and the average cost of repair, the error in the repair cost estimates could be large. If actual repair expenditures are 50 percent higher or lower than the estimated value, total costs would change by about $115 million, or 14 percent.

Administrative Costs. These costs are accurately known because BAR's administrative expenditures are budgeted by the legislature and tracked and audited by the state controller.

Cost of Motorists' Time. Economists use a number of methods to determine how people value their time. For example, in "willingness to pay" studies, researchers ask people questions about how much they would be willing to pay for various items or amenities. In "revealed preferences" studies, researchers attempt to infer valuations from the way people actually behave in various situations. Sorting out people's true values is an inexact science. Nevertheless, as noted earlier, studies suggest people value their time at somewhere between 50 percent and 100 percent of their after-tax wage rate. The IMRC used 75 percent of the average after-tax manufacturing wage rate as a reasonable estimate of how people value time spent in Smog Check.

The IMRC has no firm data on how long it takes the average motorist to go through the Smog Check process, including driving to and from the testing site and going through the test. For a passing vehicle, it is hard to see how it could take less than about 30 minutes on average. The time for a failing vehicle is less certain and probably subject to much wider variation. For some vehicles, particularly those that are "ping-ponged" between test-only and test-and-repair stations, the amount of time could be significantly more than 90 minutes. On the other hand, some repairs, such as a timing or carburetor adjustment, might add very little extra time to the process. If the motorist has his or her vehicle repaired after dropping it off on the way to work, the extra time involved might also be small. If the estimate for motorist time costs is off by 50 percent in either direction, this would change total program costs by about 5 percent.

Overall Uncertainty in Smog Check Costs. Repair expenditures and the time motorists spend in the Smog Check process likely account for the majority of uncertainty in total Smog Check costs. However, these costs are not sufficiently well known to place hard limits on the uncertainty in these values. Assuming no more than a 50 percent error in the estimates for these factors, the error in the estimate of total Smog Check costs would not exceed about $150 million or about 20 percent.

3. What Portion of Smog Check Costs Are Directed toward Repair?

In addition to total costs of the program, another key policy variable is how efficient the program is in directing expenditures toward activities that most directly realize program goals. One way to assess this is by determining what portion of Smog Check expenditures are directed toward repair of high-emitting vehicles. Table 5 breaks down Smog Check costs by the percent of costs directed toward vehicle repair. About 28 percent of Smog Check expenditures, or $237 million, are directed toward vehicle repair (this figure includes an estimated $38 million for retests of failing vehicles after repair).

One might ask how this breakdown would change if either (1) the estimates of the number of vehicles repaired, or of average repair costs were different, or (2) what might happen if changes were made to the program. If, for example, the failure rate rose to 35 percent and average repair costs rose to $250 in the Enhanced program, total costs (all other things being equal) would rise by 50 percent from $854 million to $1.3 billion, and 46 percent of total expenditures would be directed toward repair.[19] On the other hand, if, say, an additional 20 percent of vehicles were exempted from the program, but the total *number* of failing vehicles remained the same, costs would drop from $854 million to about $760 million.[20] Thirty-one percent of expenditures would then be directed toward repair.

Table 5. Percent of Smog Check Costs by Activity

	Percent of Costs		
Activity	**Enhanced**	**Basic**	**Statewide**
Repairs	29	25	28
Testing, Motorists' Time, Administration	71	75	72
Totals	100	100	100

[19] Such a scenario might occur if cut points were lowered from the their current levels down to the levels assumed by ARB in its SIP submittal to USEPA.

[20] Such a scenario might entail, for example, exempting additional newer vehicles from the program.

4. Average Costs to Motorists of Going through Smog Check

The cost to motorists of getting a Smog Check includes the costs of testing, repair (if necessary), the Smog Check certificate fee, and time spent in the Smog Check process. In the Enhanced Program, for a passing vehicle, Smog Check costs the average motorist about $65. For a failing vehicle the average motorist cost is about $210.[21]

These averages mask substantial differences in costs based on the model year of the vehicle a motorist owns. The cost differences arise for two reasons. First, average repair costs differ by model year, with repair costs for 1980s vehicles about $20 to $30 more than repair costs for 1970s and 1990s vehicles. Second, and of greater importance, failure rates are much higher for older vehicles than for newer vehicles. Thus, owners of older vehicles are more likely to incur repair costs than owners of newer vehicles. For example, at the current Phase 4 cut points, the failure rate ranges from about 25 percent to 40 percent for vehicles from the 1970s to the mid-1980s. On the other hand, failure rates are well below 10 percent for most 1990s models (see Figure 2 in Part I of this report for failure rates by model year). This means that owners of older vehicles are more likely to incur repair costs than owners of newer vehicles.

It is likely that Smog Check costs also fall disproportionately on motorists with lower incomes. The reason for this is that motorists with lower incomes are more likely to drive higher emitting vehicles.[22]

5. Cost Effectiveness of Smog Check

The cost effectiveness of a program is equal to the cost per unit of benefit achieved. In the case of Smog Check, for this analysis, cost effectiveness is assessed in terms of the cost per ton of ozone precursors eliminated.[23] This method provides an estimate of how effective the Smog Check program is in reducing pollution per dollar expended. Before

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[21] The difference between the costs for passing and failing cars is more than just repair costs. Failing cars may incur retest costs and are also more likely to have had a pretest. Finally, motorists spend more time in the Smog Check process when their cars fail.

[22] Hughes Environmental Systems (1995) "City of Los Angeles Remote Sensing Pilot Project", prepared for the City of Los Angeles Environmental Affairs Department; Singer, B.C. and R.A. Harley (2000) "A fuel-based inventory of motor vehicle exhaust emissions in the Los Angeles area during summer 1997," *Atmospheric Environment*, vol. 34, no. 11, pp. 1783-1795.

[23] Note, however, that the ultimate benefits of reduced air pollution are improved health, greater visibility, and reduced damage to crops and vegetation. These benefits are achieved by reducing ozone levels. Ozone levels are in turn reduced by reducing ozone precursors.

Ideally, one would measure cost per unit of ultimate benefit achieved, or at least, cost per unit of ozone reduction achieved. Focusing on reductions in ozone *precursors* implicitly assumes that the benefits of ozone reduction accrue in proportion to the reductions in the ozone precursors. The IMRC took this approach (as do virtually all analyses of the cost effectiveness of emissions reductions) because estimating reductions in ozone precursors entails less uncertainty than attempting to estimate resulting ozone reductions and the benefits that ensue due to ozone reductions.

Smog Check results in additional benefits that are not quantified in this analysis. For example, NOx is a precursor to peroxyacetylnitrate (PAN), a lung irritant, and also contributes to formation of particulates. Gasoline exhaust includes a number of air toxics. To the extent Smog Check reduces HC and NOx emissions, reductions in air toxics and particulates will occur as well.

presenting this analysis, two additional items must be clarified. First, one must identify the pollutants on which to focus. Second, because the Enhanced Program was added in an area that had had a Basic Program for many years, one must determine what portion of the costs and benefits to assess. These issues are discussed below in more detail.

Benefits Included. Smog Check is intended to reduce three types of pollution, CO, HC and NOx. Per ton of emissions, HC and NOx have a much greater effect on ozone production than CO. However, because total CO emissions are so much larger than HC and NOx emissions, CO does make a significant contribution to ozone formation. Estimates of ozone-forming potential suggest that, per unit mass of emissions, HC causes roughly 60 times more ozone production than CO. [24] Therefore, in the cost effectiveness calculation, every 60 tons of CO reduction is credited as the equivalent of one ton of HC reduction.

CO is also a harmful pollutant in its own right and is therefore a criteria pollutant under the Clean Air Act. However, most areas of the state are near or in attainment for CO. The cost effectiveness analysis in this report therefore credits CO reductions only for their effect on ozone reductions.

Smog Check includes gas cap pressure testing, which assesses the ability of a vehicle's gas cap to seal in gasoline vapors. The program requires replacement of gas caps that fail the test. To the extent that Smog Check is effective in identifying leaky gas caps, additional HC benefits will accrue. There are no data available to assess actual emission reductions from gas cap repairs in the Enhanced Smog Check program. However, using the EMFAC2000 model, ARB estimates that Enhanced Smog Check reduces non-tailpipe HC emissions by 26 tons per day.[25]

Relative Contribution of Basic and Enhanced Programs. The Smog Check program in its current form has existed in the most populous regions of the state since 1984. For roughly two-thirds of the vehicles in the state, the Basic Program was replaced with the Enhanced Program in June 1998.

There are at least three ways to look at the cost effectiveness of the Enhanced Program. Each of the three perspectives focuses on a different aspect of Smog Check benefits. The first perspective is to assess the total benefits of the current cycle of Smog Check (which in this case is the first cycle of the Enhanced Program). A second

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[24] The ozone forming potential of various hydrocarbons and CO is expressed as *maximum incremental reactivity* (MIR). MIR has units of grams of ozone per gram of HC (or CO). The estimated MIRs are 0.058 for CO and 3.5 for vehicle HC emissions (3.5/0.058 = 60). See Kirchstetter et al. (1999) "Impact of CA Reformulated Gasoline on Motor Vehicle Emissions. 2. Volatile Organic Compound Speciation and Reactivity" *Environ. Sci. Technol*., vol 33, pp 329-336, and Carter, W. (2000) "The SAPRC-99 Chemical Mechanism and Updated VOC Reactivity Scales" (revised draft), prepared for the California Air Resources Board, Contracts No. 92-329 and 95-308, Sacramento, California.

[25] It should be noted that the EMFAC model includes implicit assumptions regarding both the correction rate for leaky gas caps and the emission reductions that accrue from each gas cap replacement. These assumptions might not be correct. For example, the EMFAC model assumes a 95 percent correction rate of leaky gas caps due to Smog Check. However, BAR estimates based on the random roadside ASM test data that the actual correction rate is only 65 percent. EMFAC also includes assumptions about the number of cars on the road. To the extent that the actual number of on-road vehicles differs from EMFAC's assumption actual benefits will differ from the model estimate.

perspective is to assess only the *incremental* benefits of the current cycle of the Enhanced program. These are the benefits over and above those that would have been achieved had the Basic Program continued. Finally, a third approach is to assess the benefits not only of the current cycle of Smog Check, but also the residual benefits of previous cycles of Smog Check. This report includes an analysis of cost effectiveness only for total benefits of the current cycle of Enhanced Smog Check.

5.1. Data and Methods

Cost effectiveness is the ratio of total costs to total emission reductions. Because the LBNL emission reduction estimate is based on Phase 3 cut points, which were in force until October 1999, the cost effectiveness estimate will necessarily be applicable only to Phase 3. Under Phase 4, Smog Check is likely more effective, but also more expensive. Detailed analysis will be necessary to determine whether Phase 4 cut points have caused cost effectiveness to rise or fall.

Cost effectiveness is calculated by estimating the average cost per vehicle and dividing it by the average tonnage reduction per vehicle. Costs include all Smog Check expenditures and also fuel economy savings. Benefits include HC and NOx reductions and CO reductions divided by 60. Each of these factors is discussed in more detail below.

Average costs per vehicle can be generated based on the Smog Check cost analysis presented earlier. However, costs must be calculated for Phase 3 rather than Phase 4. Under Phase 3, average repair costs were slightly lower ($116 vs. $128), and fewer vehicles received official pretests. Average costs also vary by benefit scenario because under the lower-bound scenario, unofficial pretests were assumed to account for only 50 percent of the difference between on-road and Smog Check station failure rates, rather than the 75 percent assumed for the best-estimate and upper-bound scenarios. Average Smog Check costs per vehicle under Phase 3 were about $87 per vehicle under the upper-bound and best-estimate scenarios, and $86 per vehicle under the lower bound scenario.

Smog Check also results in cost savings due to fuel economy benefits. A study by Resources for the Future[26] of Arizona's I/M program estimated these benefits at about $35 per failing vehicle per I/M cycle. This study assumed gasoline prices of one dollar per gallon. Given current gasoline prices of about $1.60 per gallon[27] this figure would rise to about $56. When spread out over all vehicles rather than only failing vehicles, the savings is about $10 per vehicle in the best-estimate scenario. Including these savings reduces average costs per vehicle to about $77. Note, however, that many assumptions go into a calculation of fuel economy benefits. Furthermore, the results for Arizona might not be applicable to California.

LBNL generated estimates of average mass emission reductions per vehicle due to Smog Check, and included upper- and lower-bound scenarios as well as a "best estimate." The benefit estimate projects benefits out to two years from the time of the last Smog Check. Thus the cost effectiveness calculation accounts for benefits that persist up

[26] See footnote # 2.

[27] Average gasoline costs are from the California Energy Commission web site at http://www.energy.ca.gov/fuels/gasoline/

to two years into the future. LBNL estimates that one cycle of Enhanced Smog Check with Phase 3 cut points reduces average emissions per vehicle over a two-year period by 35, 29 and 18 pounds in the upper bound, best estimate, and lower bound scenarios, respectively.

5.2. Cost Effectiveness of Smog Check

Table 6 displays the estimated cost effectiveness range of the Smog Check Program both including and excluding estimated fuel-economy benefits.[28] In this calculation, CO reductions account for 10 to 14 percent of Smog Check benefits, depending on the scenario.

Table 6. Estimated Cost Effectiveness of First Cycle of Enhanced Smog Check

	Cost Effectiveness ($/ton)	
Scenario	**Including Fuel Economy Benefits**	**Excluding Fuel Economy Benefits**
Upper Bound	4,400	5,000
Best Estimate	5,400	6,000
Lower Bound	9,000	9,500

To put these numbers in context, Table 7 compares the estimated cost effectiveness of Smog Check with that of other air pollution reduction measures, and with estimates of the cost effectiveness of other Enhanced I/M programs. For any given program, different researchers and organizations can generate widely different cost effectiveness estimates. These differences can occur due to (1) different assumptions about the costs of implementing a measure, (2) different assumptions about the benefits of implementing a measure, and/or (3) different methods for estimating cost effectiveness. The estimates in Table 8 were drawn from independent studies that reviewed the existing studies on cost effectiveness for each program, and estimated the range of likely cost effectiveness values given the uncertainties in the available information on costs and benefits for each measure.[29]

[28] These estimates reflect uncertainty in Smog Check *emission reductions*. There is also uncertainty in the estimate for Smog Check *costs*. However, because the uncertainty in costs appears to be much smaller than the uncertainty in benefits, no separate scenarios are shown for potential cost differences.

[29] Estimates come from Dixon, L., et al. (1996) "California's Ozone Reduction Strategy for Light-Duty Vehicles: An Economic Assessment", The RAND Corporation, Institute for Civil Justice, Santa Monica, California, and Wang, M. Q. (1997) "Mobile Source Emission Control Cost-Effectiveness: Issues, Uncertainties, and Results", *Transportation Research D*, vol. 2, no. 1, pp. 43-56.

Table 7. Cost Effectiveness of Smog Check Compared with Cost Effectiveness of Other Air Pollution Control Measures[29]

Air Pollution Reduction Measure	Cost Per Ton
California Enhanced Smog Check (this analysis)	\$4,400 - \$9,000
Enhanced I/M (other programs and pre-implementation estimates)	\$500 - \$5,500
Low-Emission Vehicles (LEVs)	\$1,000 -\$38,000
Ultra-Low-Emission Vehicles (ULEVs)	\$22,000 - \$48,000
Vehicle Scrappage	\$2,000 - \$14,000
Reformulated Gasoline (RFG2)	\$3,000 - \$46,000

As Table 7 indicates, Enhanced Smog Check appears less cost effective than earlier estimates for Enhanced I/M. These earlier estimates were developed either for USEPA's generic Enhanced I/M program, or for specific Enhanced programs such as Arizona's.[30] There are three reasons why other studies estimated lower values for cost effectiveness than the value estimated for California. First, previous estimates of Smog Check cost effectiveness have generally credited each ton of CO reduction as equal to 1/7 or 1/10 of a ton of HC or NOx. These ratios were presumably used to put CO on a relatively equal footing with HC and NOx on a mass basis, because CO mass emissions are much greater than those of HC or NOx. The implicit assumption was that mass-adjusted CO reductions provided benefits equivalent to HC and NOx reductions. This study uses a factor of 60 between CO and HC to put CO on an equal footing with HC in terms of its *capacity to form ozone* rather than its mass.

Second, the cost per vehicle inspected in the California Enhanced Program is significantly higher than in other I/M programs. Third, USEPA assumed reductions greater than 30 percent for HC and CO and 7 percent for NOx when developing its cost effectiveness estimates. These values are much higher than the actual benefits of I/M programs. If actual benefits of the Enhanced Smog Check Program were as high as the USEPA assumption, cost effectiveness would improve significantly. As shown in Table 7, Enhanced Smog Check's cost effectiveness compares favorably with the cost effectiveness of other emission reduction measures.

5.3. Cost Effectiveness by Model Year

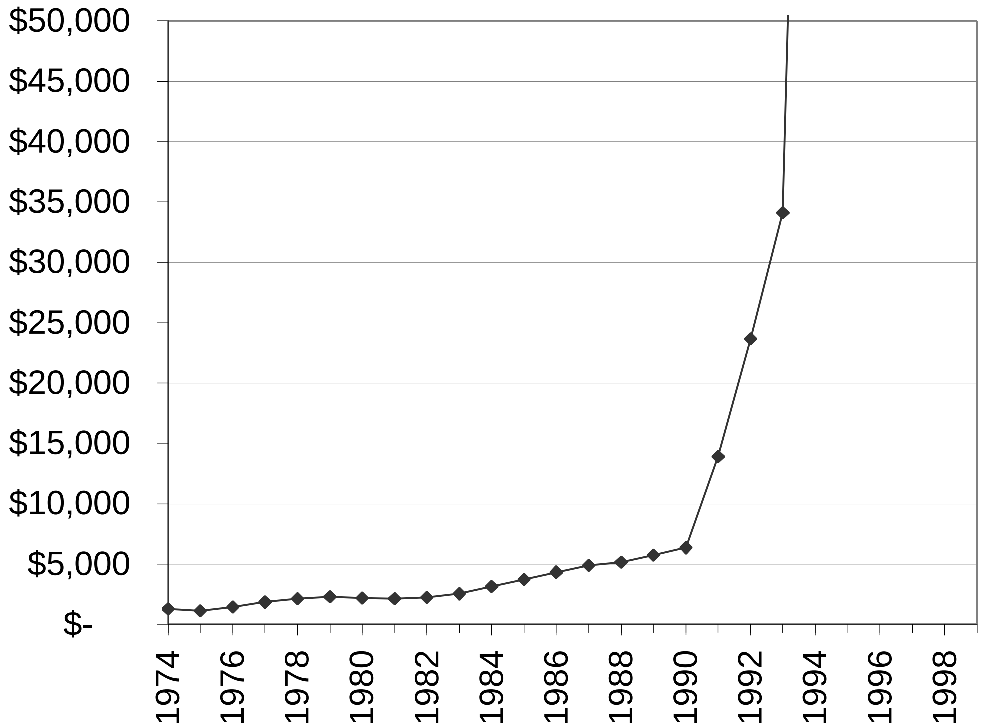
The range of vehicle model years subject to Smog Check is an important policy variable because program costs and benefits can differ a great deal across model years. Using the same methods detailed above, one can estimate the cost per ton of reductions

[30] USEPA (1992) "Enhanced I/M: Costs, Benefits, and Impacts" Ann Arbor, Michigan; Harrington, W., et al. (1999) "The Enhanced I/M Program in Arizona: Costs, Effectiveness, and a Comparison with Pre-Regulatory Estimates", Resources for the Future, Washington, DC.

achieved for each model year, rather than for the fleet as a whole. Figure 1 displays the results of this analysis under the best-estimate scenario and including estimated fuel economy benefits. Cost per ton rises slowly from older to newer vehicles through the 1990 model year, and then rises very steeply for 1991 and newer vehicles. By the 1993 model year (roughly 7 year-old vehicles at the time these data were collected), costs have risen to about $35,000 per ton.

Cost effectiveness is worse for newer vehicles for two reasons. First, fewer vehicles fail the test when they are young. Therefore, many more vehicles must be tested for each failing vehicle to be identified. Table 8 displays the cost for each failing vehicle identified in the Enhanced Program for selected model years. These values are calculated by dividing the cost per vehicle by the failure rate (including assumed unofficial pretests). In this case the appropriate cost is the cost per vehicle excluding repairs, and the appropriate failure rate is the failure rate for a given model year.[31] Second, even when newer vehicles do fail the test, their emissions are not as high, on average, as the emissions of older vehicles that fail, so the average reductions per failing vehicle are lower for newer vehicles.

Figure 1. Cost Per Ton of Reductions by Model Year in 1999 under the Best Estimate Scenario, and Including Estimated Fuel Economy Benefits



[31] Recall that costs are about $65 per passing vehicle (including testing, certificate, and motorist time costs) and failure rates are Phase 4 failure rates by model year, adjusted based on the estimate of unofficial pretests. Cost per failing vehicle identified with Phase 3 cut points would be slightly higher because failure rates were lower.

Figure 2 displays the cumulative percent of total benefits and costs incurred for each model year included in the program, based on the best-estimate scenario. Note that older vehicles provide greater benefits for a given level of expenditure. For example, pre-1991 vehicles (which were 10 or more years old in 1999) account for about 95 percent of total benefits, but only 60 percent of total costs. Thus, if 1991 and newer vehicles were exempt from Smog Check testing, costs would drop by about 40 percent and benefits would decrease by about 5 percent. Table 9 displays cost effectiveness range for three model-year ranges under the best-estimate scenario.

Table 8. Cost by Model Year to Identify Each Failing Vehicle
(Phase 4 Cut Points)

Model Year	Cost to Identify Each Failing Vehicle
1976	$170
1980	$150
1984	$160
1988	$290
1992	$570
1996	$1,500
Average	$370

Table 9. Cost Effectiveness by Model-Year Range under the Best-Estimate Scenario and Including Estimated Fuel Economy Savings

Model Year Range	Cost Effectiveness ($/ton)
1974-1983	$2,000
1984-1990	$4,700
1991-1999	$35,000
Fleet Average	$5,400

Figure 2. Cumulative Percent of Costs and Benefits of Enhanced Program Using Best-Estimate Benefit Numbers and Including Estimated Fuel Economy Benefits